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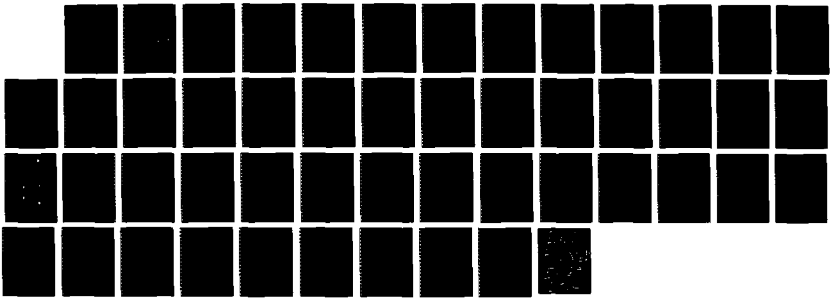

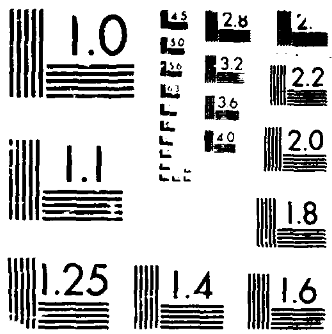
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A Forecast of Workloads and Manpower Requirements for the Archiving of Scientific & Technical Reports by the Defense Technical Information Center Using a Simulation Model :An Operations Research Approach

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Background:

At several meetings attended by the Chief of DTIC-LO, Chuck Elliott, concern was raised by several participants concerning the increasing time required to input a technical report (TR) and the growth in backlogs of TRs awaiting input. The Chief of DTIC-LO determined that this was an area that would lend itself to an operations research investigation and, through the Director of DTIC-L, requested and received the Administrator's approval to proceed with a study.

Problem:

TR input time grew from 47 days in December 1986 to 76 days in June 1988. [As of September, it had decreased to 65 days.] The backlog growth is shown in the "TR Backlog Review" section.

Constraint:

Data collection was confined to DTIC-L, with no new data requirements to be imposed upon the operations directorates. There were two purposes for this: first, to refrain from imposing workload on operating units, second, (since DTIC-L is the main repository for top management information) to determine if sufficient data are already being collected by our current automated and manual information systems for management to make decisions.

Acknowledgements:

Several people provided excellent support for this study. John Crossin did a thorough job gathering the raw data. Robert McKalvia provided valuable historical knowledge of the data collection process and the section on "Days Waiting for Input." Irvin Koch provided the detailed process flowchart which was used to develop the simplified flowchart used in this study. Without their help this study would not have been possible.

I want to thank those who patiently reviewed drafts of this study and provided valuable comments: Betty Fox, Richard Evans, John Crossin, Irvin Koch, and Robert McKalvia. The F and H Directorates did a fine job in rapidly reviewing and commenting on this paper.

Any errors in this paper are solely my own.

Methodology:

One of the first steps in any study, that of recognizing that a possible problem exists, had already been taken by the managers at DTIC even before the DTIC-LO office became involved. Alerting management to the fact that an operations research analysis might be able to help in the development of a solution was an easy matter since management has been very receptive to the concept of staff analysis studies.

There seemed to be universal agreement that backlogs were a major contributing factor to the slowdown in TR input.

> **{DTIC-H Comment: This Directorate feels that just the reverse is true. The slowdown in TR input caused a buildup in backlogs. The reasons for the slowdown in TR input follows:**
>
> 1. **The decision in Oct 87 to divert resources from the pipeline (TR input) to IR&D hard copy input.**
> 2. **A shortage of keystroking personnel.**
> 3. **The implementation of TRIS and associated problems.**
> 4. **The first three reasons had a negative effect on the length of time it took to process a cycle.**
> 5. **There were more documents being put into the system in FY 88.**
> 6. **There were problems with DROLS/RTIS stability.}**

Given this, the study focused upon determining backlog buildup factors. This naturally led to an investigation of production resources made available (mainly labor resources) and production rates. The general approach to the operations research analysis was to: examine efficiency over the past 2 years, simulate the next year, demonstrate a method of tracking efficiency (process average charting), and determine the resources needed to accomplish the program.

To provide the information needed for analysis three major steps were taken. First a determination was made as to what raw data was needed and what raw data was available (keeping in mind the self-imposed study constraint identified earlier). Second, descriptive statistics were computed and scatterplots were constructed to search for patterns. Third, a STELLA simulation model was developed to give an idea of what could be expected for the next year and to show relationships in the production process.

General:

There is a "priority queue discipline" to maintain a certain mix of documents for announcement. While not affecting the overall length of time the average TR must wait for input, this can greatly reduce the time for specific TRs.

Generally, backlogs exist in all organization sections of the TR input flow, i.e. no one is idle waiting for the arrival of a TR, which reduces the need to determine the distribution form that the arrivals take. [However, this paper does not consider DTIC-Z's operation. Computer problems could have a significant effect upon several areas of the input process. A study of this effect would be worthwhile and probably will be asked for after managers have reviewed this current study. DTIC-Z was not included in this study because it was felt that the method of analysis would be very different from that used for the other sections.]

The person equivalents shown in the "Data/Statistics" Appendix need to be interpreted. They do not mean that a specific number of people are needed by a particular section. They are provided only to put the hours processing in perspective. For example, the receiving function reported an average of 101 productive labor-hours used per month over the past two years. This could have been made up of one part-time permanent person; or 101 people, each contributing one hour a month. The data does not indicate which is the case. It also does not give an indication of support personnel whose hours are not reported against the specific workloads, such as supervisory or clerical, needed. Therefore, this person equivalent number is just a general indicator of the minimum staffing required. It is shown only to allow management to easily visualize the magnitude of organization size.

The raw data shown in the "Technical Report Workload & Labor Hours (Raw Data)" table was gathered by John Crossin and Robert McKalvia from the following reports:

- Personnel Strength & Manhour Report, RCS 1174 [Monthly LAPER (Part A)]

  FPS Received Class
  FPS Received Unclass
  FPS Hours Processing
  FDAC Hours Selecting
  HDB Hours Cataloging
  HAS Abstracted
  HAS Indexed
  HAS Hours Indexing & Abstracting
  HDS Transcribed
  HDS Hours Transcribing, Editing, MF Headers

- DTIC Form 102

  FPS Processed
  FDAC Selected
  FDAC Non-Selected

- DTIC Form 373

  HDB Cataloged
  HDB Non-Cataloged (Duplicate)

Definitions:

Average - Refers to the average over the data collection period.

Box & Whiskers - A graphical representation of a variable's descriptive statistics; used in this study to identify outliers that might distort the analysis.

Data Collection Period (DCP) - Historical observations for the period October 1986 through September 1988.

Person Equivalent - Productive labor-hours per month divided by 148 hours.

Production Rate - The number of technical reports that can be processed in one labor-hour.

Productive Labor-hours - Those hours that would be reported in LAPERS.

Rate of Change - Refers to the slope of a linear regression line fitted to the observations for the data collection period.

Simulation Period - Theoretical data for the period October 1988 through September 1989. [The data shown from the simulation run should not be confused with the historical observations from the data collection period.]

TR - Technical Report

X - TR volume. This gives the technical report volume processed through the organization element during the time period.

Y - Labor-hours. This gives the labor-hours used by the organization element during the time period.

X / Y - TRs processed per hour. This gives the technical report volume processed per labor-hour through the organization element during the time period. This is used in computing the total current capacity of the organization element; and it is also used in determining the labor-hours needed to handle a given workload or to process a given backlog. This shows the level of efficiency for the period, and following this number over time will show the changes in efficiency over time (with an increase in this number demonstrating an improvement in efficiency).

Y / X - Time required to process one TR. This gives the time required to process one technical report through the organization element during the time period. Adding this time up for each organization element will give the total time it could take to process the typical technical report all the way through the input process. This shows the level of efficiency for the period, and following this number over the data collection periods will show the changes in efficiency over time (with a reduction in this number over time demonstrating an improvement in efficiency). The sum for all organization elements shows the theoretical time through the system. It will vary from the actual time due to delays in starting work on a TR (most probably due to the TR being in a backlog), and delays waiting for batch processing.

Assumptions:

1. Assume the Divisions accurately reported their workloads and labor-hours or that any inaccuracies are at an insignificant level.

2. Assume TR variations (such as classified/unclassified, large/small, good quality/poor quality) occur randomly. [This assumption is needed since TRs are not homogeneous and each variation requires a different amount of work.]

3. Assume personnel turnover rate during the data collection period is representative of the normal situation.

4. Assume personnel turnover rate during the simulation period does not differ from the rate existing during the data collection period.

5. Assume personnel learning curve during the data collection period is representative of the normal situation.

6. Assume personnel learning curve during the simulation period does not differ from the learning curve existing during the data collection period.

7. Assume each organization element had a backlog for each time period during the data collection period, i.e. there was never a period of idle labor.

8. Assume quality of production remains constant throughout the data collection period and the simulation period.

9. Assume the workload measured is the only unit of production from the organization element and that time spent on work other than that being measured is insignificant.

Relaxation of Assumptions:

The relaxation of any of the above assumptions could have anywhere from a minor to a major effect upon the results of this study due to the impact upon the organization element processing rate. While any combination of relaxations of assumptions could be modeled, it would require building a more sophisticated model than is felt to be needed given the scope of this study. (Assumptions 1, 2 and 9 cannot be relaxed to any significant degree and retain confidence in the final numbers.)

Efficiency:

Changes in efficiency can be monitored by comparing the output of the conversion process to the input needed. In this case dividing the volume of technical reports processed by the labor-hours needed, will give the number of technical reports processed per labor-hour. Reviewing this number over time will reveal the trend in productivity and the percentage change in productivity.

For purposes of this study, only labor efficiency is being considered. Any substitution of capital for labor is ignored. It is assumed that there has been no significant substitution of capital for labor during the relevant time periods. If there have been significant substitutions of capital for labor then the efficiency figures developed in this study overstate the true efficiency.

The analysis of efficiency makes use of the following two equations plus process average charts (shown elsewhere):

$$\text{\% Efficiency Change Each Year} = \frac{\text{(slope of X/Y regression line)} \times 12}{\text{intercept of X/Y regression line}} \times 100\%$$

$$\text{\% Variation in Efficiency Over the DCP} = \frac{\text{Max of X/Y - Min of X/Y}}{\text{Min of X/Y}} \times 100\%$$

Production Rate:

As used in most sections of this study, the production rate means the number of TRs produced in one labor-hour of effort (with hours of effort being as reported in the LAPER A report). Overhead hours that would not be reported against the relevant workload are not analyzed.

Factors affecting the production rate of the conversion process are illustrated by the following equation:

Production Rate = f (Fatigue, Morale, Turnover, Learning Curve, Changes in the Process, Initial Ability of the Employee, Initial Capacity of the Employee, Supervision, Attention of Management, Quality of the Initial TR, Training, Time on the Job, Availability of Equipment, etc.)

These items have not been explicitly built into the mathematical model; however, some of these items could be added, given information which is not currently available.

The variation in the production rate can be determined by comparing the maximum to the minimum of **X/Y** for each organization element, as discussed under "efficiency." A review of the process average charts also will show any variation.

Days Waiting for Input:

The following description of days a TR must spend waiting to be input was provided by Robert McKalvia of DTIC-LRE.

Days Waiting is calculated from the date of receipt in Selection to the date of the Master File update. Based on the FY89 TR Input program of 32,000 divided by the average workdays of 250 per year, 128 TRs are scheduled daily. The backlogs in Selection (DTIC-FDAC) and Descriptive Cataloging (DTIC-HDB) are divided by 128 to determine the number of workdays each document will remain in backlog before an AD number is assigned. From AD number assignment in Cataloging to the Master File update is an average of 24 workdays. If the Master File update is behind schedule, the number of workdays late is added to the scheduled 24 workdays.

Days Waiting = Workdays Backlogged in Selection + Workdays Backlogged in Cataloging
+ 24 + Workdays Late for Master File Update

In December 1986, this amounted to a 47 day wait. In June 1988, this peaked at 76 days. By September 1988, the wait had dropped to 65 days.

FPS Receiving:

The analysis in this section is based upon the information shown in the "FPS-Receiving; Descriptive Statistics" table.

A review of the hours devoted to receiving showed that only a little over 100 productive labor-hours per month was devoted to the task of receiving. It was also readily apparent that the hours used bore little relationship to the number of documents processed. Therefore the more detailed analysis that was used in some of the other areas, where measures of efficiency were computed, was not used for this area.

The coefficient of correlation (a measure of the strength of the relationship between variables - the coefficient of determination, a stronger test, was not needed after a review of the data) for each variable was so low that it is clear that linear regression would not be useful as a forecasting tool. This was further confirmed by a review of scatterplots (not shown in this paper); however, over the two year period there has been a general trend growth of 16 documents received per month. This cannot be used to forecast the next month's receipts; however, it does indicate that DTIC could expect to receive more in the next year than in years past and that the program is growing. The wide variation between the maximum and minimum values of TRs received showed that there were significant fluctuations from month to month.

Data on classified and unclassified documents (the first two columns) is shown only to give an idea of the total volume of reports received. These first two columns are not used in subsequent analysis. There seems to be a 3:1 ratio of total documents coming in the door to total documents sent to selecting (the difference being duplicate copies). This item may be of value in determining the space needed to handle the volume of documents received.

The average TRs processed through FPS Receiving over the past two years was used as the initial input to the simulation model for documents submitted to DTIC. The slope of a time series linear regression line (discussed below) was used as a growth factor in the simulation for each subsequent month. While the true submission growth was random, using a constant growth factor will still reveal the general situation.

FDAC Selecting:

The analysis in this section is based upon the information shown in the "FDAC-Selecting; Descriptive Statistics" table.

There is an excellent increase in efficiency shown over the past two years (8.23% each year); however, the variation in efficiency (52.87%) is dramatic. The coefficient of correlation for the linear regression line for all variables is too low to use this as a forecasting method. A review of scatterplots confirms this. The great variation in labor-hours available, maximum of 1162 and minimum of 696, could be expected to make managing the function difficult. The coefficient of correlation (.42) for a linear regression line for the efficiency measure of this organization, while being much higher that many others, still is not sufficient for forecasting.

Non-Selected represents approximately eight percent of the total TRs sent to FDAC for selecting. There is no indication of how much processing the TR receives prior to being judged to be a "non-select TR"; however, the ratio of selected to non-selected changes little over the relevant period. Therefore inclusion or exclusion of non-selected in the workload figures over the relevant period will not have a significant effect on the percent change in efficiency per year. However, it does need to be taken into account in the simulation model and indeed it is explicitly shown. [The eight percent non-selected have made it through the process up to this point. If these eight percent were washed out prior to any selecting processing there may be a saving of effort. However, this may not be possible.]

The person equivalents averaged 6 over the DCP. There was a maximum of 8 and a minimum of 5. However, if we intend to process all the TRs that are submitted to us and eliminate the backlog, we should be averaging around 7 person equivalents each month (12487 productive labor-hours for the full year). [This assumes no change in the average production rate.]

A "process average" chart was developed for this function (see the "FDAC Selecting Process Average Oct 86 - Sep 88" figure) since an efficiency measure was able to be developed from the data. Ideally we would want to have each succeeding dot falling above the preceding dot. The average line would be recomputed with each new dot and slowly move upward - giving a general trend of increasing efficiency and, through efficiency's effect upon productivity, a general trend of increasing productivity (making note of the assumption made when measuring efficiency that quality is a constant). FDAC may want to adopt this type of chart in tracking efficiency.

The average production rate (X/Y) and the average labor-hours available was used in the simulation run to determine what we could expect this organization to produce. [The November outlier was excluded based upon a Box and Whiskers analysis so that results would not be distorted.]

HDB Cataloging:

The analysis in this section is based upon the information shown in the "HDB Cataloging; Descriptive Statistics" table.

There is a slight increase in efficiency shown over the past two years (0.09% each year); however, the variation in efficiency (41.61%) is significant. The coefficient of correlation for the linear regression line for all variables is too low to use this as a forecasting method. The great variation in labor-hours available, maximum of 1714 and minimum of 816, could be expected to make managing the function difficult. The coefficient of correlation for a linear regression line for the efficiency measure of this organization indicated that we can have no confidence in the direction efficiency is taking using time as an independent variable. However, there did seem to be a pattern emerging so a second degree polynomial equation was fitted to the data. This gave a coefficient of correlation of .52 which, while being significantly better than the linear equation, is still too low to be useful for forecasting. Other independent variables were not tried for a variety of reasons.

Non-Cataloged represents approximately four percent of the total TRs sent to HDB for cataloging. There is no indication of how much processing the TR receives prior to being judged to be a "non-catalog TR"; however, the ratio of cataloged to non-cataloged changes little over the relevant period. Therefore inclusion or exclusion of non-cataloged in the workload figures over the relevant period will not have a significant effect on the percent change in efficiency per year. However, it does need to be taken into account in the simulation model and indeed it is explicitly shown. [The four percent non-cataloged have made it through the process up to this point. If these four percent were washed out prior to selecting there may be a saving of effort. However, this may not be possible.]

> **{DTIC-H Comment: DTIC-F used to check for duplicates in the selection process and wash them out before the cataloging process began. We found this to be inefficient and discontinued the process, eliminating the need for five positions.}**

The person equivalents averaged 9 over the DCP. There was a maximum of 12 and a minimum of 6. However, if we intend to process all the TRs that are submitted to us and eliminate the backlog, we should be averaging around 11 person equivalents each month (19814 productive labor-hours for the full year). [This assumes no change for the average production rate.]

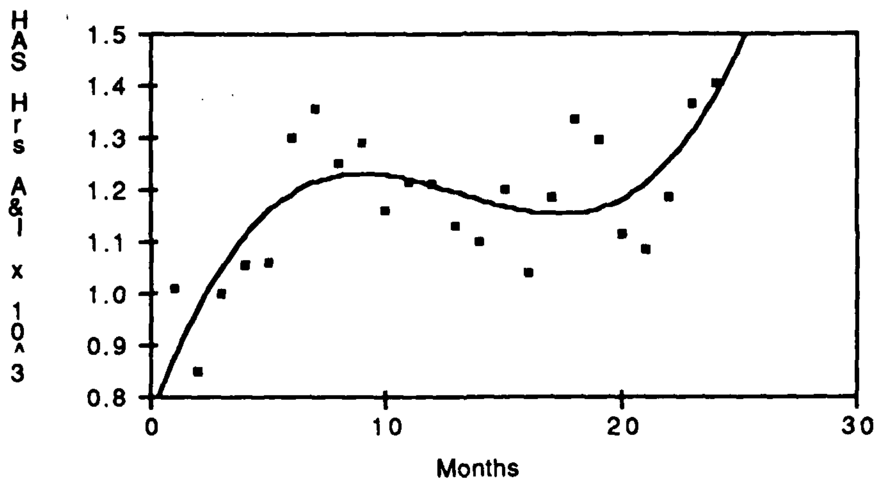
A "process average" chart was developed for this function (see the "HDB Cataloging Process Average Oct 86 - Sep 88" figure) since an efficiency measure was able to be developed from the data. Ideally we would want to have each succeeding dot falling above the preceding dot. The average line would be recomputed with each new dot and slowly move upward - giving a general trend of increasing efficiency and, through efficiency's effect upon productivity, a general trend of increasing productivity (making note of the assumption made when measuring efficiency that quality is a constant). HDB may want to adopt this type of chart in tracking efficiency.

The average production rate (X/Y) and the average labor-hours available was used in the simulation run to determine what we could expect this organization to produce.

HAS Abstracting/Indexing:

The analysis in this section is based upon the information shown in the "HAS Abstracting/Indexing; Descriptive Statistics" table.

The workloads for abstracting and indexing are reported separately; however, there is no separation of the hours worked. Therefore, it was not possible to provide meaningful process average charts for these functions, or to do much detailed analysis of this section. However, an interesting pattern emerged when a third order polynomial equation was fitted to the data with the hours worked as the dependent variable and time as the independent variable. This pattern is displayed below. The coefficient of correlation was 0.77, which is not exceptionally high, yet the curve helps in visualizing a general pattern. Certainly no extrapolation is possible using this curve, but if we confine ourselves to interpolation we get the feeling that there was a reverse roller coaster effect occurring. That is, the abstracting/indexing function would pick up speed (curve going up) for a while, then suffer a reverse in direction and slow down (curve going down) for a while in hours being devoted to this function; and follow this as a cyclical pattern.



Once again, we see a pattern of great volatility in the labor-hours being devoted to the function, with a range of 850 to 1403 in labor-hours made available.

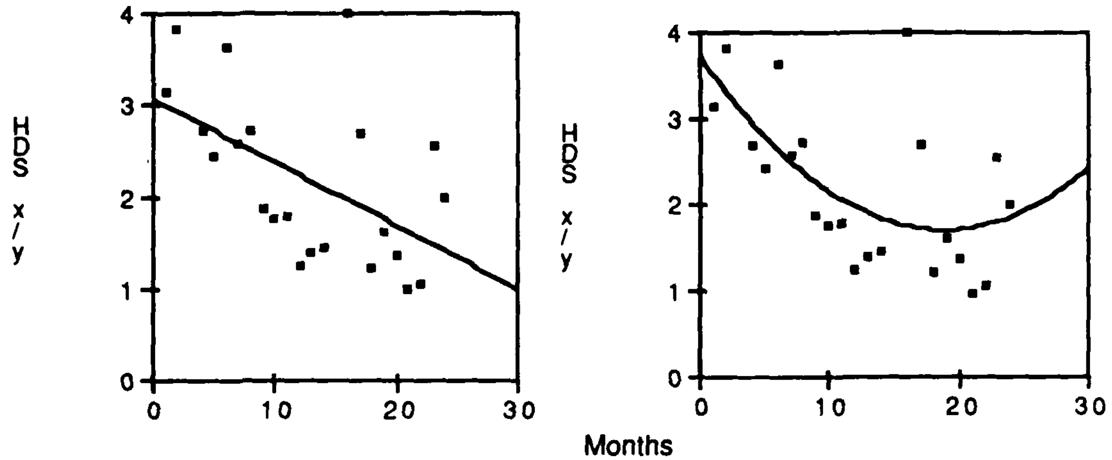
The person equivalents averaged 8 over the DCP. There was a maximum of 9 and a minimum of 6. However, if we intend to process all the TRs that are submitted to us and eliminate the backlog, we should be averaging around 11 person equivalents each month (19392 productive labor-hours for the full year). [This assumes no change for the average production rate.]

For the simulation model the average production was used for each area, rather than the more detailed production rate and average labor-hours available.

HDS Transcribing:

The analysis in this section is based upon the information shown in the "HDS Transcribing; Descriptive Statistics" table.

The data for transcribing gives an indication of major difficulties being experienced with every measure. Labor-hours made available varies greatly with a range extending from 510 hours to 1746 hours. The efficiency measure, TRs produced per labor-hour, ranged from 0.98 to 3.99. An initial look at the change in efficiency over the past two years yielded a very disturbing trend, a linear regression line (with a coefficient of correlation of only 0.54) showing a negative 27 percent change in efficiency each year; however, a closer inspection using a second order polynomial gives a different perspective, with a bottoming in efficiency about six months ago and an upturn in efficiency in more recent months (with a coefficient of correlation of 0.61).



The person equivalents averaged 7 over the DCP. There was a maximum of 12 and a minimum of 3. However, if we intend to process all the TRs that are submitted to us and eliminate the backlog, we should be averaging around 10 person equivalents each month (17683 productive labor-hours for the full year). [This assumes no change for the average production rate.]

A "process average" chart was developed for this function (see the "HDS Transcribing Process Average Oct 86 - Sep 88" figure) since an efficiency measure was able to be developed from the data. Ideally we would want to have each succeeding dot falling above the preceding dot. The average line would be recomputed with each new dot and slowly move upward - giving a general trend of increasing efficiency and, through efficiency's effect upon productivity, a general trend of increasing productivity (making note of the assumption made when measuring efficiency that quality is a constant). HDS may want to adopt this type of chart in tracking efficiency.

> **{DTIC-H Comment: Our efficiency was greatly affected by the turbulence in staffing. We were required to use large amounts of overtime, which caused variation in the production rate due to the fatigue factor. We also had to use borrowed labor, which caused variation in the production rate due to the learning curve effect.}**

Season Effect:

The data (displayed in the "Season Effect" figure) was examined for seasonal patterns and organizational patterns, eg. do such factors as the Xmas season influence tne production rate?; is there something that spreads throughout the organization that causes an across the board change in the production rate?

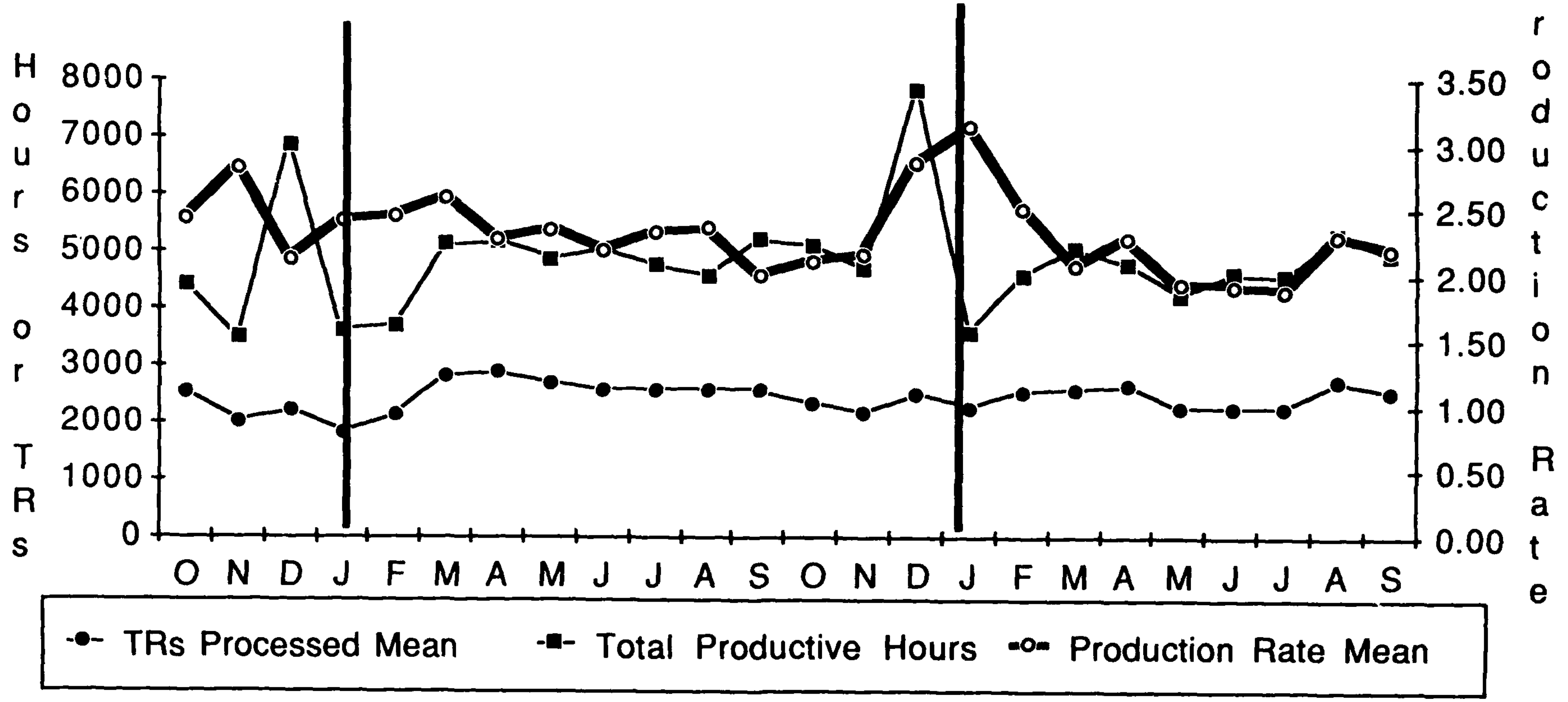
Three items were selected for analysis:

First, the mean of the TRs processed. This is the mean of TRs processed through five sections: receiving, selecting, cataloging, abstracting/indexing, and transcribing. There should not be a great deal of volatility for this item since problems that are isolated to one organization element would tend to be blended out. The fact that there does seem to be a great deal of volatility indicates system wide problems. December seems to be one of the high points in the year for volume. This would not rationally be expected to occur and may indicate a reporting aberration for December and January for volume.

Second, the total productive hours. This is the total number of hours reported for all five sections. It gives a good indication of DTIC capacity. It should reflect general trends in total labor available to do work. One would expect this to remain relatively constant unless there were a hiring freeze in effect, then there would be a general trend downward, or unless there were a beefing up in production, then there would be a general trend upward. Any season effect should be very noticeable here, with people taking vacations having a major impact (unless major uses of overtime were made to keep production up); however, December shows an amazing effect of being far higher, and January far lower, in hours worked than other months. This gives a strong indication that there is some aberration in reporting hours.

Third, the mean of the production rates. This is the mean of production rates for three sections: selecting, cataloging, and transcribing. Receiving was excluded due to the small amount of hours devoted to the effort and the dramatic variations in output to input (indicating that there is no relationship between the hours invested in receiving and the amount received). Abstracting and indexing could not be included since there was no breakdown of the labor-hours between functions. The mean of the production rates should be the most stable element of all, if DTIC's input function were under control. Instead it is highly volatile. If there is no reporting error in the raw data then this is an area that needs to be addressed by management since fluctuations in this rate could be the major factor in determining backlog. This study will not speculate as to what may be causing such dramatic volatility. The reasons could range from those that are readily acceptable, such as TR variations not occurring randomly, or aberrations in reporting (due to cutoff dates on reports), to those that would indicate major problems in managing the work force. [Hopefully the volatility is due to reasons that would be readily acceptable.]

Season Effect



Frequency/Probability Tables:

The analysis in this section is based upon the information shown in the "Production Rate (X/Y) Frequency/Probability Distribution" and "Labor-hours Available Frequency/ Probability Distribution" tables.

Production Rate (X/Y) Frequency Distribution

The production rate table shows the frequency of occurrence for a particular number of TRs to be produced for one labor-hour of effort. For example, in "selecting" the production rate fell between 2.40 and 2.49 TRs processed per labor-hour for two months during the data collection period. The frequency columns do not add up to the expected 24 due to outliers that were excluded from the data to prevent distortion. The selection of outliers was made by "box & whisker" analysis.

Noting the assumptions made at the beginning of the study, it could be expected that production rate frequencies of occurrence would approximate a tight normal curve if the production process were under control. Normality tests were conducted for each of the three sections. A significance value below 0.05 would be evidence that the frequency distribution was not normal. All three were above 0.05 (FDAC with 0.356, HDB with 0.25, and HDS with 0.27) therefore it cannot be concluded that any of the three have an other than normal distribution. (This normality test has certain limitations which may make its use in the context of this study questionable; however, there are more important considerations than if the frequency distribution is normal.) Next came a measure of the dispersion of the frequency distribution. Comparing the standard deviation to the average can give a feeling for the spread of the frequencies. FDAC had a SD/Avg of 0.10, HDB had a SD/Avg of 0.10, and HDS had a SD/Avg of 0.42. There is no specific number with this test that tells if the process is in or out of control; however, the closer to 0 the better. The range is also a measure of dispersion. The range for FDAC was 2.33 to 3.56 TRs processed per labor-hour; for HDB 1.66 to 2.35 TRs processed per labor-hour; and for HDS 0.98 to 3.99 TRs processed per labor-hour. These are rather major variations and indicate a conversion process that may not be in control.

Production Rate Probability Distribution

This section of the table shows the percentage of months that had a specific production rate. For example, for FDAC, four percent of the months during the data collection period had a production rate that fell between 2.30 and 2.39 TRs processed per labor-hour. Quite often this type of analysis is used to determine an expected value. In some cases it can be used to find the value of perfect information. The analysis is not taken further in this study.

Labor-hours Available Frequency Distribution

The labor-hours available table shows the frequency of occurrence for a particular amount of labor-hours to be made available to a production unit. For example, in "selecting" the labor-hours available fell between 700 and 799 labor-hours for two months during the data collection period. The frequency columns do not add up to the expected 24 due to outliers that were excluded from the data to prevent distortion. The selection of outliers was made by "box & whisker" analysis.

This gives an indication of the resources that DTIC made available to these production sections. It does not show the total picture of labor made available to the organization element since manufacturing overhead that was necessary but not reported against the workload is not included in this data.

Given the continuous backlog existing in each area, one would expect that there would be a steady amount of labor-hours made available to these organization elements. Such is not the case from the data reported. The labor-hours made available varies widely. The range gives a clear view of this variability. The ranges were: FDAC from 696 to 1162; HDB from 816 to 1714; HAS from 850 to 1403; HDS from 510 to 1746. Such wide variability can have grave implications for the production process. One would expect managers to have a difficult time managing such a volatile work force.

Labor-hours Available Probability Distribution

This section of the table shows the percentage of months that had a specific labor-hours available amount. For example, for FDAC, four percent of the months during the data collection period had labor-hours available that fell between 600 and 699 labor-hours. Quite often this type of analysis is used to determine an expected value. In some cases it can be used to find the value of perfect information. The analysis is not taken further in this study.

Production Rate (X/Y) Frequency/Probability Distribution Table

Production Rate	Frequency of Occurence Selecting FDAC	Cataloging HDB	Transcribing HDS	Probability of Occurence Selecting FDAC	Cataloging HDB	Transcribing HDS
.9s			1			0.05
1.0s			1			0.05
1.2s			2			0.09
1.3s			1			0.05
1.4s			2			0.09
1.6s		1	1		0.04	0.05
1.7s		8	1		0.33	0.05
1.8s		4	2		0.17	0.09
1.9s		3			0.13	
2.0s		3	1		0.13	0.05
2.1s		3			0.13	
2.2s		1			0.04	
2.3s	1	1		0.04	0.04	
2.4s	2		1	0.09		0.05
2.5s	1		2	0.04		0.09
2.6s	3			0.13		
2.7s	3		3	0.13		0.14
2.8s	2			0.09		
2.9s	4			0.17		
3.0s	2			0.09		
3.1s	3		1	0.13		0.05
3.2s	1			0.04		
3.5s	1			0.04		
3.6s			1			0.05
3.8s			1			0.05
3.9s			1			0.05
TOTAL =	23	24	22	1	1	1

Labor-hours Available Frequency/Probability Distribution Table

Labor-hours Available	Frequency of Occurence Selecting FDAC	Cataloging HDB	Abs/Index HAS	Transcribing HDS	Probability of Occurence Selecting FDAC	Cataloging HDB	Abs/Index HAS	Transcribing HDS
500s				1				0.05
600s	1			1	0.04			0.05
700s	2			1	0.09			0.05
800s	4	1	1	4	0.17	0.04	0.04	0.18
900s	8		7	1	0.35		0.29	0.05
1000s	5	2	5	4	0.22	0.08	0.21	0.18
1100s	3	8	6	3	0.13	0.33	0.25	0.14
1200s		3	4	2		0.13	0.17	0.09
1300s		4	1	1		0.17	0.04	0.05
1400s		1		1		0.04		0.05
1500s		2		1		0.08		0.05
1600s		1				0.04		
1700s		2		2		0.08		0.09
TOTAL =	23	24	24	22	1	1	1	1

TR Processing Capacity:

The analysis in this section is based upon the information shown in the "TR Processing Capacity" table.

The conversion process' capacity to input TRs is a function of the four inputs [human effort (labor-hours available), land (space) , capital (equipment), and raw materials (TRs)]. This report assumes that the limiting factor is human effort and that within the relevant range the other three factors do not serve as constraining factors. A study could be conducted to consider the other factors as constraining; however, the benefits of doing so for this study would be minor and it would require violating the study constraint in that data would have to be collected from outside of DTIC-L.

Capacity is the maximum volume of output per time period that we could theoretically achieve given our current input mix. Capacity can be measured in two ways. There is peak capacity. This is when everything is worked to the maximum (maximum overtime, no shutdowns for periodic maintenance, etc.). By definition it cannot be maintained over a long period of time. And there is sustainable capacity. This is when everything is operated at a rate that can be maintained into the reasonable future.

Volume is the actual amount that is processed. It should not be confused with capacity which is a theoretical amount.

Four theoretical capacities (I am blurring the distinction between actual historical volume and theoretical capacity) were computed for each section.

The optimistic capacity assumes that the section will produce at its best production rate ever achieved and be given the maximum amount of labor-hours it has ever had. It is not realistic but rather sets the upper boundary of what could be produced.

The average capacity uses the average labor-hours available times the average production rate for three of the sections, and the average amount produced for the other three sections. This is the most realistic capacity that can be expected. These numbers are used in the simulation model to provide a forecast of what can be expected. They are also used to determine what level of labor-hours should be made available if we desire to accomplish our desired program. [In the case of receiving, a "growth factor" is included for the simulation run.]

The most frequent capacity takes information from the frequency/probability table. It is shown only to give an idea of what would happen if the most frequent situation were to happen every time. While close to the average capacity it should not be used in further analysis since the frequency distributions have a very great range and no one frequency clearly dominates for any section.

The pessimistic capacity assumes that the section will produce at its worst production rate ever achieved and be given the minimum amount of labor-hours it has ever had. It is not realistic but rather sets the lower boundary of what could be produced.

> **{DTIC-H Comment: We recommend that an analysis of equipment and software be included in an analysis of processing capacity. We feel that RTIS/TRIS has been a major problem.}**

TR Processing Capacity				
Receiving:				
	Hours Available	Production Rate	TR Total per Month	TR Total per Year
Optimistic			3625	43500
Average			2870	34440
Most Frequent				
Pessimistic			1971	23652
Selecting:				
	Hours Available	Production Rate	TR Total per Month	TR Total per Year
Optimistic	1162	3.56	4137	49641
Average	954	2.86	2728	32741
Most Frequent	950	2.95	2803	33630
Pessimistic	696	2.33	1622	19460
Cataloging:				
	Hours Available	Production Rate	TR Total per Month	TR Total per Year
Optimistic	1714	2.35	4028	48335
Average	1280	1.92	2458	29491
Most Frequent	1150	1.75	2013	24150
Pessimistic	816	1.66	1355	16255
Abstracting:				
	Hours Available	Production Rate	TR Total per Month	TR Total per Year
Optimistic			3038	36456
Average			2140	25680
Most Frequent				
Pessimistic			1110	13320
Indexing:				
	Hours Available	Production Rate	TR Total per Month	TR Total per Year
Optimistic			3183	38196
Average			2316	27792
Most Frequent				
Pessimistic			1630	19560
Transcribing:				
	Hours Available	Production Rate	TR Total per Month	TR Total per Year
Optimistic	1746	3.99	6967	83598
Average	1100	2.18	2398	28776
Most Frequent	950	2.75	2613	31350
Pessimistic	510	0.98	500	5998

Simulation:

One simulation run was made using the model shown at the "Simulation Model" figure. The equations underlying the model are shown in the "Simulation Model Equations" table. And the numerical results are shown in the "Simulation Run Results" table. This run was based upon the following:

1. Average production for all elements. This takes the "average production" and "average labor-hours available," demonstrated during the data collection period, and holds it constant at that average rate for the simulation run.

There could have been many more runs made such as:

2. Changing rate of production for all elements. This would use a linear regression, built upon the data collection period, to forecast the production rate for each iteration of time during the simulation run. As such, the production rate would change for each time period. However, the change in production rate in our organization elements have been erratic and, while complicating the model, inclusion would probably not improve the results.

3. Using the frequency distribution of production rates. This would use the frequency distribution developed for each organization element plus a random number generator to determine a new production rate for each month of the simulation period. It could be expected to give a slightly more accurate model of what we could expect; however, it would greatly complicate the model and be much more difficult to understand. The improvement in the forecast would not be expected to outweigh the disadvantages.

4. Relaxing some of the assumptions and building them explicitly into the model. This has the most potential, not so much for coming up with a more accurate forecast but for the benefits to be derived from the model construction process itself. In fact, the particular simulation software used (STELLA) derives much of its value from managers explicitly having to build the model and seeing the inputs. For example, the production rate can be built upon several factors, one being the learning curve. When managers see the learning curve's effects they can realize the importance of the factor and take steps to improve the training process. This also is the most arduous model and calls for great involvement on the part of the managers.

Due to the lack of breakdown for HAS hours, the simulation was run with the abstracting and indexing rates equal to the average production shown over the DCP and not using the product of the average hours times the average labor-hour production rate that was used for some other areas. One interesting feature is the "Min Processing" detour some TRs take around the abstracting function. This minimum processing function was set equal to the difference between the abstracting rate and the indexing rate, which is why the "Index Backlog" tank is always 0.0.

Each "tank" has a capacity of 3000 TRs. Which is why the TRs Transcribed tank is full. The TRs Transcribed tank can be set at the program level to see if it will fill up under various alternatives. That is not demonstrated here so that the analysis will not become overly complex. To see the actual accumulation in each tank by month see the simulation run results.

There is no constraint or "governor" set on any section. That is, it is assumed that backlog will be worked on instead of a section sitting idle or reducing labor-hours made available waiting for the output of the preceding section. For example, indexing is producing at 2316 per month yet the TRs transcribed is permitted to grow at 2398 per month, which is the production rate of transcribing.

Simulation Run Results

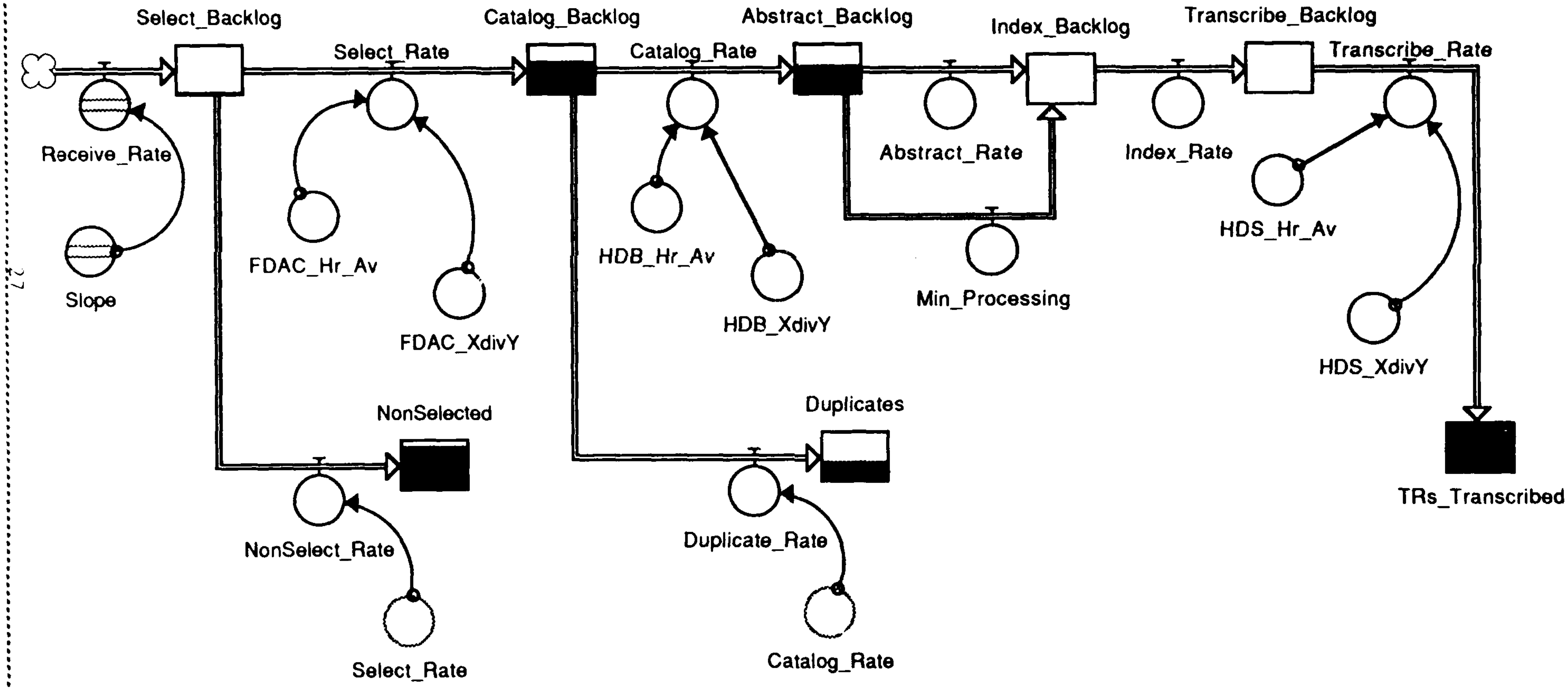
Month	Abstract Backlog	Catalog Backlog	Catalog Duplicates	Index Backlog	NonSelect	Select Backlog	Transcribe Backlog	TRs Transcribed
0	0	0	0	0	0	0	0	0
1	142	167	104	0	223	-82	-82	2398
2	283	333	208	0	447	-148	-164	4796
3	425	500	313	0	670	-197	-246	7194
4	566	667	417	0	893	-231	-328	9592
5	708	833	521	0	1117	-249	-410	11990
6	850	1000	625	0	1340	-251	-492	14388
7	991	1166	729	0	1563	-237	-574	16786
8	1133	1333	834	0	1787	-206	-656	19184
9	1274	1500	938	0	2010	-160	-738	21582
10	1416	1666	1042	0	2233	-98	-820	23980
11	1558	1833	1146	0	2457	-20	-902	26378
12	1699	2000	1251	0	2680	75	-984	28776

The negative numbers for select backlog and transcribe backlog indicate excess capacity. Note that the negative numbers are so small as to be insignificant - indicating no real excess capacity.

A "Box & Whiskers" analysis was conducted of the raw data to identify any potential outliers that should be considered for elimination.

The amount received for inputting from suppliers was forecast from the DCP. The equation for the forecast is $Y=2870+16X$. This forecasting equation gives an expected submission to DTIC of 35496 TRs in FY 1989. As can be seen from the results of the simulation, the throughput is 28776. This throughput could easily be changed with a change in labor-hours made available or a change in production rates.

The simulation was run on a forecast of how many TRs could be expected (notice the "received" equation in the simulation model); rather than being run on the 32,000 FY 89 program for input. Since we cannot influence the submission of TRs (in any but the most general way) it may be inappropriate for DTIC to use any other method than a forecast of what we can expect to receive. Programing and providing the resources to do 32,000 inputs (instead of forecasting submissions) will mean that our backlog levels will not be determined by DTIC but will be determined by our suppliers. This in turn would mean that our suppliers would be determining our TR input waiting time rather than ourselves.


Select_Backlog
Catalog_Backlog
Abstract_Backlog
Index_Backlog
Transcribe_Backlog
Select_Rate
Catalog_Rate
Transcribe_Rate
Receive_Rate
Abstract_Rate
Index_Rate
FDAC_Hr_Av
HDB_Hr_Av
HDS_Hr_Av
Slope
Min_Processing
FDAC_XdivY
HDB_XdivY
HDS_XdivY
NonSelected
Duplicates
TRs_Transcribed
NonSelect_Rate
Duplicate_Rate
Select_Rate
Catalog_Rate

Simulation Model Equations

```
□ Abstract_Backlog = Abstract_Backlog + dt * ( Catalog_Rate - Abstract_Rate - Min_Processing )
    INIT(Abstract_Backlog) = 0
□ Catalog_Backlog = Catalog_Backlog + dt * ( Select_Rate - Duplicate_Rate - Catalog_Rate )
    INIT(Catalog_Backlog) = 0
□ Duplicates = Duplicates + dt * ( Duplicate_Rate )
    INIT(Duplicates) = 0
□ Index_Backlog = Index_Backlog + dt * ( Abstract_Rate - Index_Rate + Min_Processing )
    INIT(Index_Backlog) = 0
□ NonSelected = NonSelected + dt * ( NonSelect_Rate )
    INIT(NonSelected) = 0
□ Select_Backlog = Select_Backlog + dt * ( -Select_Rate + Receive_Rate - NonSelect_Rate )
    INIT(Select_Backlog) = 0
□ Transcribe_Backlog = Transcribe_Backlog + dt * ( -Transcribe_Rate + Index_Rate )
    INIT(Transcribe_Backlog) = 0
□ TRs_Transcribed = TRs_Transcribed + dt * ( Transcribe_Rate )
    INIT(TRs_Transcribed) = 0
○ Abstract_Rate = 2140
○ Catalog_Rate = HDB_Hr_Av*HDB_XdivY
○ Duplicate_Rate = Catalog_Rate*(103/2429)
○ FDAC_Hr_Av = 954
○ FDAC_XdivY = 2.86
○ HDB_Hr_Av = 1280
○ HDB_XdivY = 1.92
○ HDS_Hr_Av = 1100
○ HDS_XdivY = 2.18
○ Index_Rate = 2316
○ Min_Processing = 2316-2140
○ NonSelect_Rate = Select_Rate*(222/2712)
○ Receive_Rate = 2870+Slope
○ Select_Rate = FDAC_Hr_Av*FDAC_XdivY
○ Slope = TIME*16
○ Transcribe_Rate = HDS_Hr_Av*HDS_XdivY
```

Labor-hours Forecast for FY 89:

The analysis in this section is based upon the information shown in the "Annual Labor-hours Requirement Forecast for FY 89" table.

The labor-hours forecast for FY 89 was approached from two directions. First, a forecast of hours needed was prepared based on the program amount of TRs that DTIC intended to process. Second, a forecast of hours needed was prepared based on the number of TRs that DTIC could expect to receive. [The hours needed to process backlogs is addressed elsewhere.]

The second forecast, based upon a projection of 35,496 TRs being submitted to DTIC, shows the amount of resources that need to be put into processing to cause a steady state to be reached, i.e. no increase or decrease in backlogs occurring [and therefore no change in the days a TR spends waiting for input].

The personnel equivalents should not be confused with staffing. The important numbers are the productive labor-hours needed. These are the labor-hours that will be reported in APCAPS against the specific workload. The FY 89 forecast numbers show a decreasing amount as the workload goes through the system due to the "non-selected" TRs not being passed on from selecting, and "duplicate" TRs not being passed on from cataloging.

Annual Labor-Hours Requirement Forecast for FY 89			
FY 89 Program =	**32000**		
Operation	Production Rate	Productive Hours Needed	Personnel Equivalents
Receiving	28.42	1126	0.6
Selecting	2.86	11189	6.3
Cataloging	1.92	16667	9.4
Abs/Ind	1.97	16235	9.1
Transcribing	2.18	14679	8.3
FY 89 Forecast =	**35496**	Submitted to DTIC	
	35496	Receiving & Selecting	
	32816	Cataloging	
	31565	Abstracting/Indexing & Trancribing	
Operation	Production Rate	Productive Hours Needed	Personnel Equivalents
Receiving	28.42	1249	0.7
Selecting	2.86	12411	7.0
Cataloging	1.92	17092	9.6
Abs/Ind	1.97	16014	9.0
Transcribing	2.18	14479	8.2
Note: Personnel Equivalents are based on 148 productive hours a month.			

TR Backlog Review:

The analysis in this section is based upon the information shown in the "TR Input Backlog for Each Organization Element" table.

Three items impact on the backlog: available labor-hours, the production rate, and the submission of TRs. Available labor-hours are a function of resources given to the organization element. The production rate function is addressed in the "Production Rate" section. A forecast of the submission of TRs is provided in the "Simulation" section. [This forecast is strictly a numerical forecast based upon the past two years. It does not attempt to identify underlying factors that may play a major role in altering submissions (such as increased or decreased IG or marketing activities).]

The display of the productive labor-hours needed to eliminate the backlog may be useful in the budget justification process.

The "Productive Labor-hours needed" shows the amount of hours of productive overtime (or other non-normal time) that would be needed to eliminate backlogs. No "person equivalent" information is shown for backlog, since normally backlog reduction in the government is handled by temporary additions to the work force or by the use of overtime. The periods do not relate to a specific unit of time but rather just serve to illustrate the backlog being processed through the system. Of course, in order to keep disruption to a minimum the backlog would probably be reduced gradually over the course of the year.

This discussion of backlog elimination is predicated upon staffing to handle 35,496 TRs normally, without the use of overtime or temporary additions. For an analysis of capacity see the "TR Processing Capacity" section, the "Simulation" section, or the "Labor-hours Forecast for FY 89" section. If staffing is not adequate to process the forecasted submission of TRs then we may face increases in our backlogs.

TR Input Backlog for Each Organization Element

	1 Oct '86	1 Oct '87	1 Oct '88	Source:
FPS	n.a.	n.a.	n.a.	
FDAC	194	1811	218	DTIC Form 102 (no archival backlog included)
HDB	1835	1648	5026	DTIC Form 373(includes 1650 archival backlog)
HAS	181	299	1640	DTIC Form 82 (no archival backlog included)
HDS	212	537	326	DTIC Form 54 (no archival backlog included)
Change in Backlog		'86 to '87	'87 to '88	
FDAC		1617	-1593	
HDB		-187	3378	
HAS		118	1341	
HDS		325	-211	

Labor-Hours Required to Eliminate Backlog Existing on 1 Oct 88

Operation	Backlog Period 1	Period 2	Period 3	Period 4	Total Volume	Production Rate	Productive Hours Needed
Selecting	218				218	2.86	76
Cataloging	5026	201			5227	1.92	2722
Abs/Ind	1640	4825	193		6658	1.97	3378
Transcribing	326	1640	4825	193	6984	2.18	3204

(8% used for non-selected; 4% used for duplicate dropped)

TR Archival Backlog Review:

The analysis in this section is based upon the information shown in the "TR Input Archival Backlog for Each Organization Element" table.

Archival backlog represents those unannounced documents that meet certain criteria. These criteria are: age and determination by originator or sponsor. It is felt that there would be little demand for these documents and they are being processed only as part of DTIC's mission to act as an archive for R&D documents.

There are two groups of these documents: 1,650 documents received some processing (*selection only*) *before a decision* was made to take these documents out of the processing queue to let higher priority documents move ahead; 9,600 documents [a rough count] have received no processing at all.

There is no current plan to process any of these documents as long as our current workload and labor-hours available remain unchanged.

If we were to process these documents it would take 18,537 labor-hours of effort. If minimum processing were used, these documents would take less time.

The 9,600 documents take up about 100 square feet in a storage room. The 1,650 documents are sitting in piles in working areas.

The 1,650 documents are included in the analysis throughout this paper. The 9,600 documents are only included in the archival section.

TR Input Archival Backlog for Each Organization Element							
	1 Oct '88		Source:				
FPS	n.a.						
FDAC	9600		Rough physical count by LRE				
HDB	1650		Physical count by LRE				
HAS	0						
HDS	0						
Labor-Hours Required to Eliminate Archival Backlog Existing on 1 Oct 88							
Operation	Backlog						Productive
	Period 1	Period 2	Period 3	Period 4	Total Volume	Production Rate	Hours Needed
Selecting	9600				9600	2.86	3357
Cataloging	1650	8832			10482	1.92	5459
Abs/Ind	0	1584	8479		10063	1.97	5105
Transcribing	0	0	1584	8479	10063	2.18	4616
(8% used for non-selected; 4% used for duplicate dropped)						Total	18537
						Person Equivalents	10

Conclusions:

- We can expect our annual TR processing capacity to be the following:

Selecting	32741
Cataloging	29491
Abstracting	25680
Indexing	27792
Transcribing	28776

- We should anticipate receiving 35,496 TRs for input in FY 89. [This does not mean staffing to process 35,496 TRs in each organization element. See the "Labor-hours Forecast for FY 89" section.]

- Impact upon the production rate, and not upon labor-hours available, will be where our managers can have the most effect upon total production. If our production rates had been stable over the past 2 years then we could assume that we would only be able to have a significant impact upon total production by varying the hours made available; however, with the great variation in rates, our managers can have a dramatic effect upon total output by providing an environment which leads to rates near our past maximums.

- There is a great deal of volatility in the labor-hours we make available to our managers to process their workloads. Past staffing practices have not been effective in providing the labor-hours needed to have an adequate stable level of human effort. (Since most of the authority for the management activity of "staffing" rests with DASC-K, much of the accountability for this failure should also rest with DASC-K. They have not provided the innovative kind of personnel management that DTIC needs.)

- There is a great deal of volatility in our production rates. Measures of efficiency have not been adequately developed and changes in efficiency have not received enough attention. (The DIMES program provides measures of efficiency; however, these do not seem to be widely used in the management process for a variety of reasons.)

- This review of the TR inputting system is incomplete. The major factor of the DTIC-Z mainframe computer impact on inputting has not been analyzed.

Recommendations:

- That measures of efficiency, similar to the process averages shown in this paper, be developed and used in following the efficiency of the TR input process.

- That measures of efficiency be shown at the DTIC Monthly Management Review.

- That positive changes in efficiency be used as justification to reward employees.

- That DTIC actively prod DASC-K into developing innovative approaches to DTIC's unique staffing problems.

- That DTIC-LO continue the analysis of problems with TR inputting through a study of the impact of DTIC-Z mainframe computer availability upon the TR input process.

Directorate Comments:

Comments on this study were solicited from DTIC-F and DTIC-H. For DTIC-F's comments, see the enclosed IOM, 17 Jan 89, Subject: Technical Report Input Workload (following page). For DTIC-H's comments, see pages 6, 14, 16, and 23, where their comments were highlighted and included in the body of the study.

Three important questions were raised in paragraph two of the DTIC-F IOM. I believe that answers to these questions will be found as the concepts of Total Quality Management and Statistical Process Control are introduced at DTIC; and as people attend the workshops in statistics that this office expects to be conducting.

The significant point mentioned in paragraph three of the DTIC-F IOM is expected to be addressed in the anticipated follow-on study "Computer Availability Impact Study." This "Technical Report Input Study" only took the process up to the point of DTIC-Z involvement, since the microphotography and filing processes occur after this point they were not included in this study.

DEFENSE LOGISTICS AGENCY

Inter-Office Memorandum

IN REPLY REFER TO DTIC-F (Mr. Gould/46864/mek)

17 JAN 1989

SUBJECT: Technical Report Input Workload

TO: DTIC-L

1. Reference: DTIC-L IOM W/encl, 27 Dec 88, subject as above.

2. The enclosure to the reference was reviewed with keen interest by the DTIC-F staff. In general, comments were most favorable and elicited such questions as: (a) will the results of this study improve workflow efficiency? (b) what significance can be made of the use of figures for this report (see p. 19) that differs from the DIMES standard? and (c) how can we better understand the terminology throughout, even with a definitions section?

3. In particular, a significant point was raised: if this study is concerned with the input processing, how can we ignore microphotography (including development and inspection) and filing--all of which are important functions in the input process? They, too, must be factored into any "get-well" decisions which are finally decided upon.

4. Overall, the study seems well conceived and we look forward to establishing the methods, procedures, and resources for implementation.

CHARLES E. GOULD
Director, Directorate
of Document Services

DLA FORM 111 PREVIOUS EDITION MAY BE

DEFENSE LOGISTICS AGENCY

Inter-Office Memorandum

1 FEB 1989

IN REPLY REFER TO DTIC-HD (Ms. Linn/46815/bjl)

SUBJECT: Technical Report Input Workload

TO: DTIC-L

1. Reference: DTIC IOM, 27 Dec 88, subject as above.

2. Our comments have been annotated on the document forwarded with the reference (Enclosure 1).

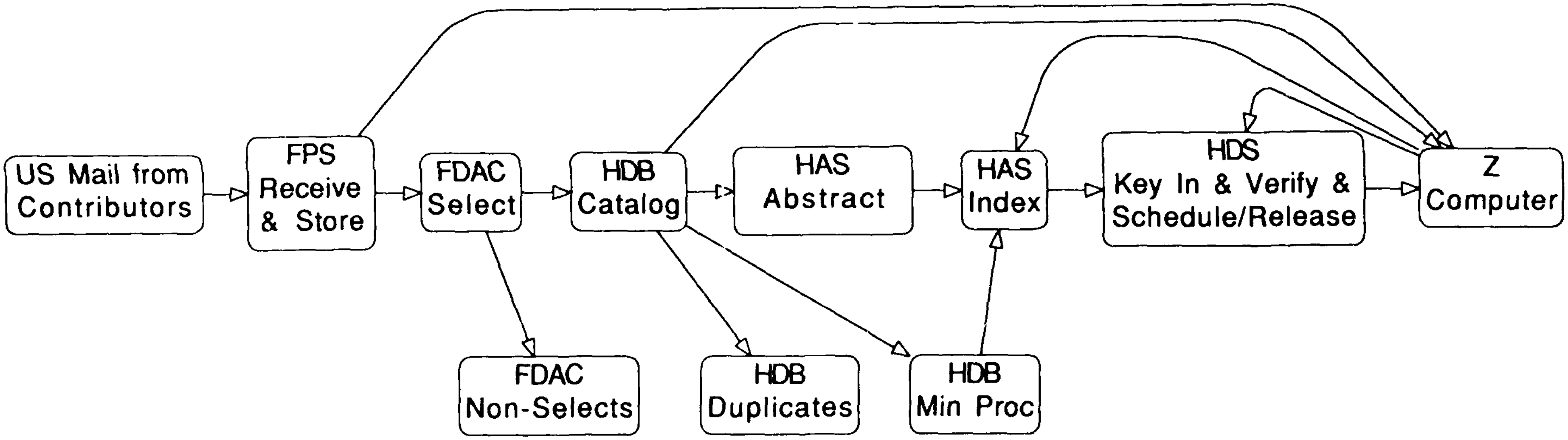
F E Murfree

1 Encl

FULLER E. MURFREE
Acting Director, Directorate of
Database Services

PREVIOUS EDITION MAY BE

Technical Report Input Processing (simplified)



Technical Report Workload & Labor Hours (Raw Data)

Period	FPS Received Class (includes duplicate copies)	FPS Received Unclass (includes duplicate copies)	FPS Processed	FPS Hours Processing	FDAC Selected	FDAC Non-Selected	FDAC Hours Selecting	HDB Cataloged
Oct.86	460	8794	3020	156	2809	257	1162	2206
Nov	620	5940	2318	65	1874	187	952	2084
Dec	427	6938	2296	106	2208	203	947	2443
Jan.87	no data	4792	2041	61	2055	406	766	2039
Feb	1286	7968	2347	137	2121	159	696	2147
Mar	492	8070	2781	146	2786	507	1116	2901
Apr	404	9068	3105	148	2646	231	1061	2705
May	266	9024	3625	130	2617	277	998	2496
Jun	309	6390	2678	69	2979	195	1099	2721
Jul	579	8565	3283	81	2865	152	909	2359
Aug	652	8320	3030	30	2535	208	859	2612
Sep	473	9623	3615	143	2675	204	963	2396
Total	***5968***	***93492***	***34139***	***1272***	***30170***	***2986***	***11528***	***29109***
Oct	631	10842	3369	56	3151	260	1021	2192
Nov	533	7499	2649	114	2855	418	875	2073
Dec	923	10710	2789	91	3026	199	849	2210
Jan.88	677	6777	1971	58	2450	111	780	1865
Feb	433	6770	2966	184	2755	158	946	2167
Mar	687	7626	3011	40	3307	109	1128	2668
Apr	562	6730	3208	114	3034	323	962	2846
May	616	7370	3186	no data	2495	152	898	2220
Jun	530	5499	3187	no data	2958	321	1000	2748
Jul	463	6520	2543	no data	2654	276	928	2331
Aug	384	7579	3087	120	2784	156	1057	2989
Sep.88	388	6290	2773	78	2622	149	926	2877
Total	***6827***	***90212***	***34739***	***855***	***34091***	***2632***	***11370***	***29186***

Technical Report Workload & Labor Hours (Raw Data)

HDB Non-Cataloged (Duplicate)	HDB Hours Cataloging	HAS Abstracted	HAS Indexed	HAS Hours Indexing & Abstracting	HDS Transcribed	HDS Hours Transcribing, Editing, MF Headers
66	1238	2366	2123	1008	2778	884
64	1124	1755	2090	850	1951	510
106	1269	2521	1666	1000	3572	560
76	1087	1446	1630	1055	1760	649
90	1126	2092	2382	1060	1720	707
104	1707	2548	2837	1300	3142	865
149	1520	2856	3183	1354	2841	1103
129	1430	1895	2727	1248	2924	1072
115	1355	2251	2559	1288	2336	1243
97	1111	2018	2415	1161	2662	1517
103	1110	2415	2561	1217	2460	1365
110	1197	1931	2684	1211	2108	1700
1209	***15274***	***26094***	***28857***	***13752***	***30254***	***12175***
79	1181	1110	1864	1128	2438	1746
113	1158	1671	1735	1099	2136	1467
80	1024	2079	2356	1200	4680	1378
115	816	1831	1859	1042	3587	898
111	1100	2121	2123	1183	3160	1172
111	1287	2477	2594	1337	1533	1261
165	1358	2817	2394	1297	1702	1058
89	1336	2281	2160	1116	1194	881
123	1518	1657	2063	1086	985	1008
96	1335	1739	3135	1187	1179	1122
262	1714	3038	1846	1364	2648	1041
140	1609	2452	2599	1403	1863	931
1484	***15436***	***25273***	***26728***	***14442***	***27105***	***13963***

FPS - Receiving; Descriptive Statistics				
Period	Received Class	Received Unclass	Processed	Hours Processing
	(includes duplicate copies)			
Oct.86	460	8794	3020	156
Nov	620	5940	2318	65
Dec	427	6938	2296	106
Jan.87	no data	4792	2041	61
Feb	outlier	7968	2347	137
Mar	492	8070	2781	146
Apr	404	9068	3105	148
May	266	9024	3625	130
Jun	309	6390	2678	69
Jul	579	8565	3283	81
Aug	652	8320	3030	30
Sep	473	9623	3615	143
Oct	631	10842	3369	56
Nov	533	7499	2649	114
Dec	923	10710	2789	91
Jan.88	677	6777	1971	58
Feb	433	6770	2966	184
Mar	687	7626	3011	40
Apr	562	6730	3208	114
May	616	7370	3186	no data
Jun	530	5499	3187	no data
Jul	463	6520	2543	no data
Aug	384	7579	3087	120
Sep.88	388	6290	2773	78
Average	523	7654	2870	101
Slope	3	-30	16	-1
Intercept	489	8032	2669	111
Coeff Cor (R)	0.12	0.14	0.25	0.14
Std Dev	147	1527	450	43
Max	923	10842	3625	184
Min	266	4792	1971	30
	Approximate person equivalents used at 148 hours/month:			
			Average =	1
			Maximum =	1
			Minimum =	0

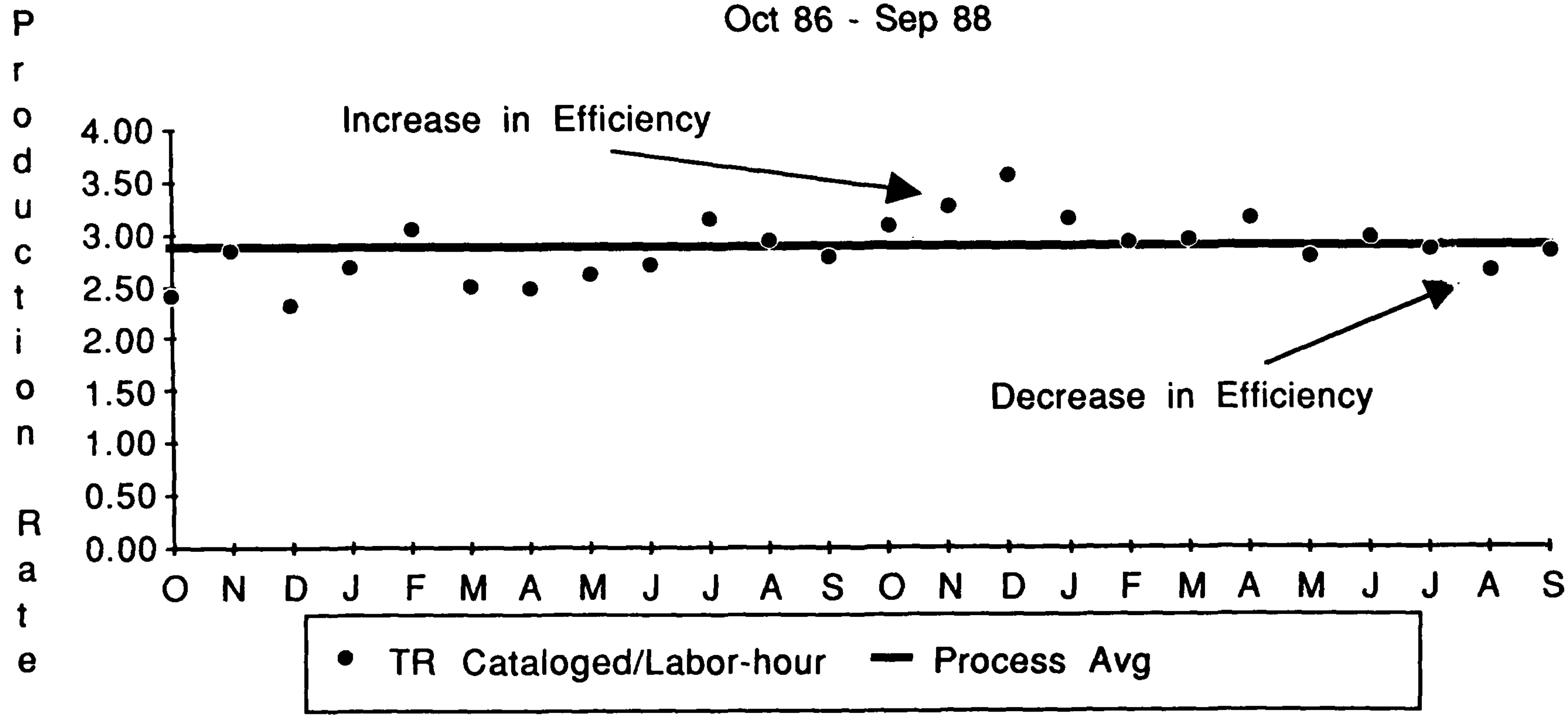
FDAC - Selecting; Descriptive Statistics					
	X		Y	X/Y	Y/X
Period	Selected	Non-Selected	Hours Selecting	(efficiency measure)	(efficiency measure)
Oct.86	2809	257	1162	2.42	0.41
Nov	outlier	187			outlier
Dec	2208	203	947	2.33	0.43
Jan.87	2055	406	766	2.68	0.37
Feb	2121	159	696	3.05	0.33
Mar	2786	outlier	1116	2.50	0.40
Apr	2646	231	1061	2.49	0.40
May	2617	277	998	2.62	0.38
Jun	2979	195	1099	2.71	0.37
Jul	2865	152	909	3.15	0.32
Aug	2535	208	859	2.95	0.34
Sep	2675	204	963	2.78	0.36
Oct	3151	260	1021	3.09	0.32
Nov	2855	418	875	3.26	0.31
Dec	3026	199	849	3.56	0.28
Jan.88	2450	111	780	3.14	0.32
Feb	2755	158	946	2.91	0.34
Mar	3307	109	1128	2.93	0.34
Apr	3034	323	962	3.15	0.32
May	2495	152	898	2.78	0.36
Jun	2958	321	1000	2.96	0.34
Jul	2654	276	928	2.86	0.35
Aug	2784	156	1057	2.63	0.38
Sep.88	2622	149	926	2.83	0.35
Average	2712	222	954	2.86	0.35
Slope	18	- 2	0	0.02	0.00
Intercept	2481	246	959	2.63	0.39
Coeff Cor (R)	0.39	0.15	0.02	0.42	0.47
Std Dev	313	84	120	0.30	0.04
Max	3307	418	1162	3.56	0.43
Min	2055	109	696	2.33	0.28
	% Δ In Efficiency For Each Year =			8.23%	
	% Variation in Efficiency Over The DCP =			52.87%	
Approximate person equivalents used at 148 hours/month:					
		Average =	6		
		Maximum =	8		
		Minimum =	5		

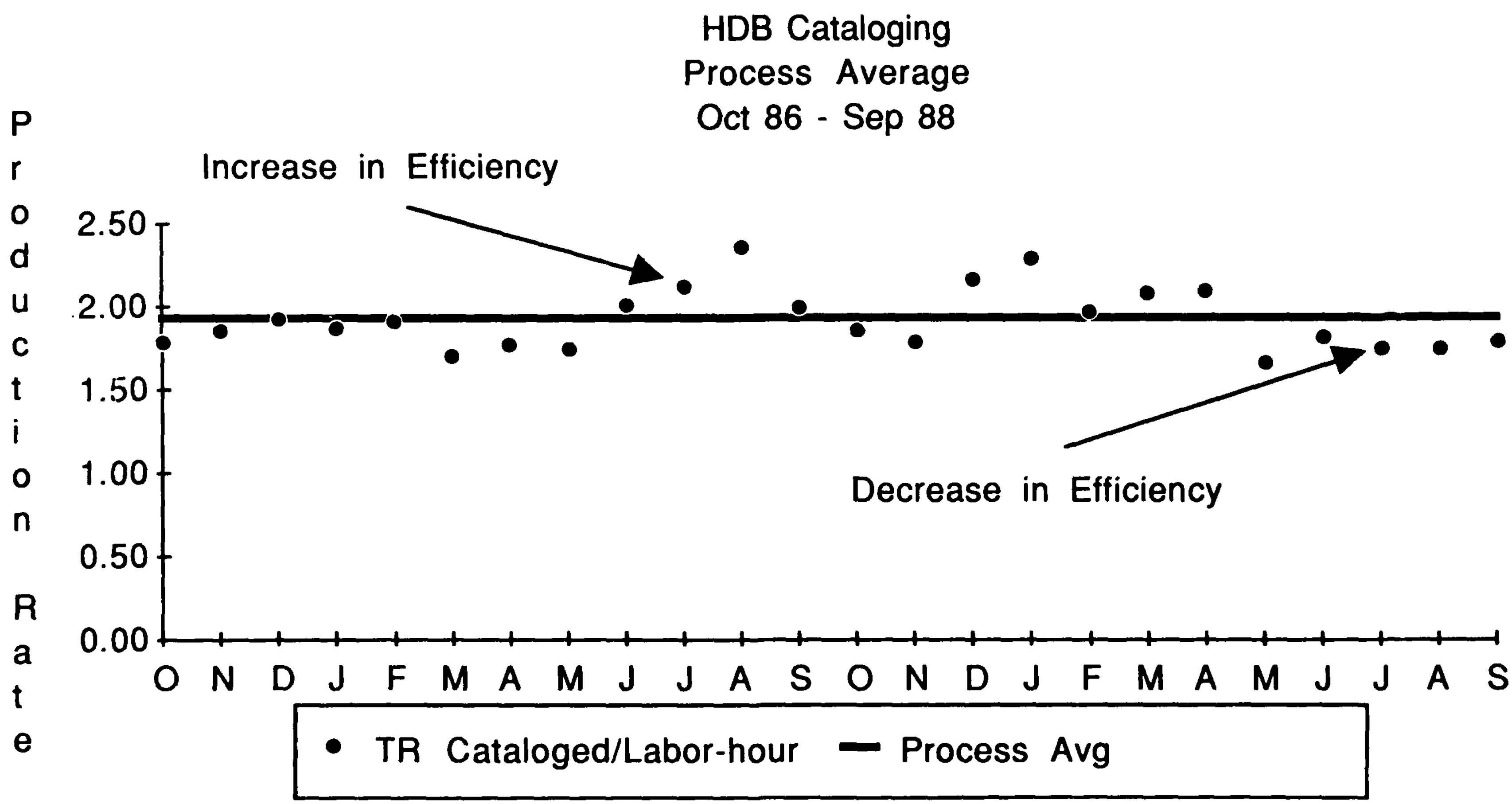
HDB - Cataloging; Descriptive Statistics					
	X		Y	X/Y	Y/X
Period	Cataloged	Non-Cataloged	Hours Cataloging	(efficiency	(efficiency
		(Duplicate)		measure)	measure)
Oct.86	2206	66	1238	1.78	0.56
Nov	2084	64	1124	1.85	0.54
Dec	2443	106	1269	1.93	0.52
Jan.87	2039	76	1087	1.88	0.53
Feb	2147	90	1126	1.91	0.52
Mar	2901	104	1707	1.70	0.59
Apr	2705	149	1520	1.78	0.56
May	2496	129	1430	1.75	0.57
Jun	2721	115	1355	2.01	0.50
Jul	2359	97	1111	2.12	0.47
Aug	2612	103	1110	2.35	0.42
Sep	2396	110	1197	2.00	0.50
Oct	2192	79	1181	1.86	0.54
Nov	2073	113	1158	1.79	0.56
Dec	2210	80	1024	2.16	0.46
Jan.88	1865	115	816	2.29	0.44
Feb	2167	111	1100	1.97	0.51
Mar	2668	111	1287	2.07	0.48
Apr	2846	outlier	1358	2.10	0.48
May	2220	89	1336	1.66	0.60
Jun	2748	123	1518	1.81	0.55
Jul	2331	96	1335	1.75	0.57
Aug	2989	outlier	1714	1.74	0.57
Sep.88	2877	140	1609	1.79	0.56
Average	2429	103	1280	1.92	0.53
Slope	14	1	8	0.00	0.00
Intercept	2251	88	1179	1.92	0.52
Coeff Cor (R)	0.32	0.38	0.26	0.00	0.02
Std Dev	319	22	221	0.19	0.05
Max	2989	149	1714	2.35	0.60
Min	1865	64	816	1.66	0.42
	% Δ In Efficiency For Each Year =			0.09%	
	% Variation in Efficiency Over The DCP =			41.61%	
Approximate person equivalents used at 148 hours/month:					
		Average =	9		
		Maximum =	12		
		Minimum =	6		

HAS - Abstracting/Indexing; Descriptive Statistics			
Period	Abstracted	Indexed	Hours Indexing & Abstracting
Oct.86	2366	2123	1008
Nov	1755	2090	850
Dec	2521	1666	1000
Jan.87	1446	1630	1055
Feb	2092	2382	1060
Mar	2548	2837	1300
Apr	2856	3183	1354
May	1895	2727	1248
Jun	2251	2559	1288
Jul	2018	2415	1161
Aug	2415	2561	1217
Sep	1931	2684	1211
Oct	1110	1864	1128
Nov	1671	1735	1099
Dec	2079	2356	1200
Jan.88	1831	1859	1042
Feb	2121	2123	1183
Mar	2477	2594	1337
Apr	2817	2394	1297
May	2281	2160	1116
Jun	1657	2063	1086
Jul	1739	3135	1187
Aug	3038	1846	1364
Sep.88	2452	2599	1403
Average	2140	2316	1175
Slope	7	5	10
Intercept	2052	2253	1055
Coeff Cor (R)	0.11	0.88	0.50
Std Dev	466	436	136
Max	3038	3183	1403
Min	1110	1630	850
Approximate person equivalents used at 148 hours/month:			
		Average =	8
		Maximum =	9
		Minimum =	6

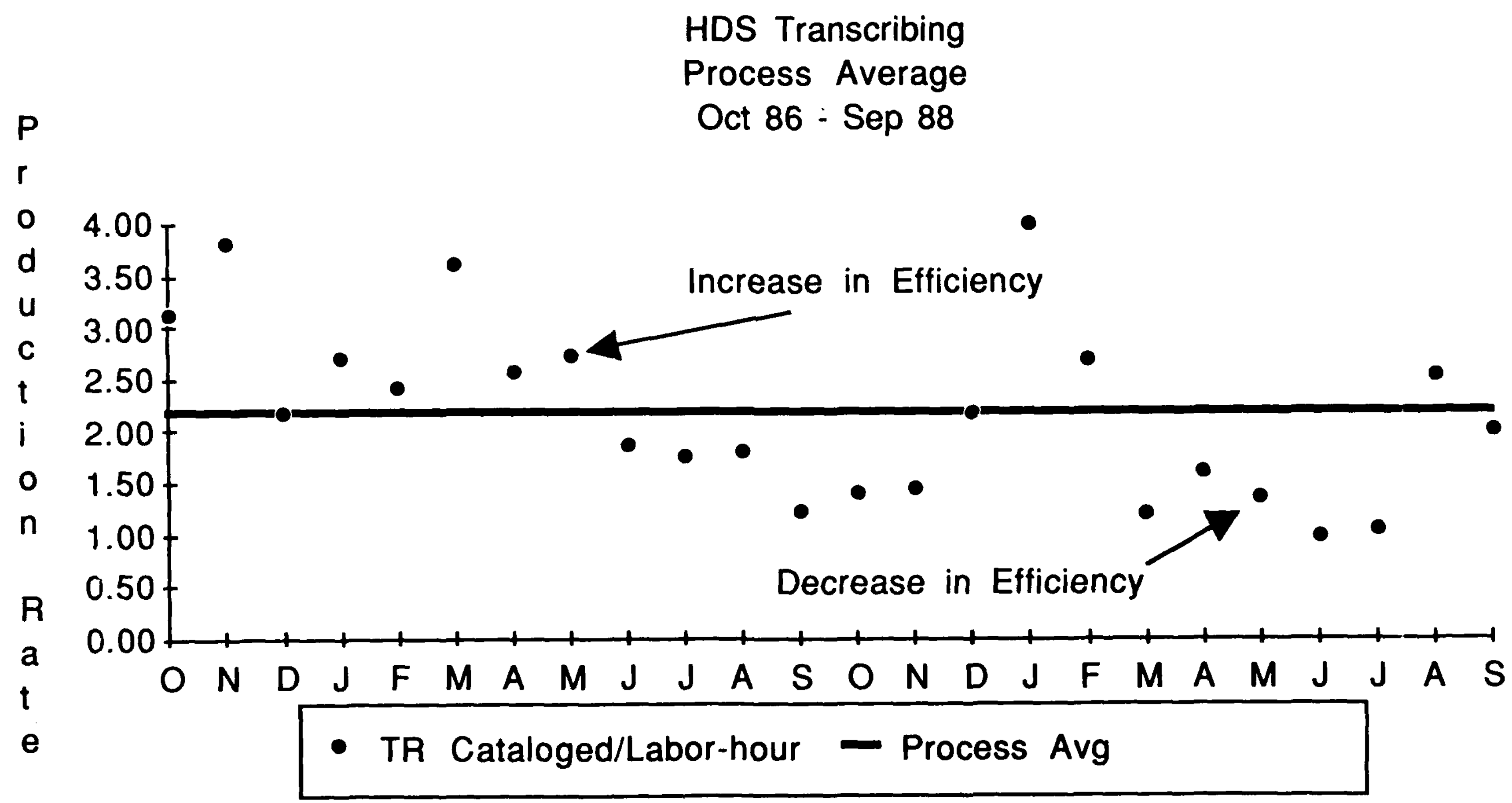
HDS Transcribing; Descriptive Statistics				
	X	Y	X/Y	Y/X
Period	Transcribed	Hours Transcribing,	(efficiency	(efficiency
		Editing, MF Headers	measure)	measure)
Oct.86	2778	884	3.14	0.32
Nov	1951	510	3.83	0.26
Dec			outlier	
Jan.87	1760	649	2.71	0.37
Feb	1720	707	2.43	0.41
Mar	3142	865	3.63	0.28
Apr	2841	1103	2.58	0.39
May	2924	1072	2.73	0.37
Jun	2336	1243	1.88	0.53
Jul	2662	1517	1.75	0.57
Aug	2460	1365	1.80	0.55
Sep	2108	1700	1.24	0.81
Oct	2438	1746	1.40	0.72
Nov	2136	1467	1.46	0.69
Dec	outlier			
Jan.88	3587	898	3.99	0.25
Feb	3160	1172	2.70	0.37
Mar	1533	1261	1.22	0.82
Apr	1702	1058	1.61	0.62
May	1194	881	1.36	0.74
Jun	985	1008	0.98	1.02
Jul	1179	1122	1.05	0.95
Aug	2648	1041	2.54	0.39
Sep.88	1863	931	2.00	0.50
Average	2232	1100	2.18	0.54
Slope	-34	11	-0.07	0.02
Intercept	2674	964	3.00	0.31
Coeff Cor (R)	0.35	0.24	0.54	0.56
Std Dev	703	320	0.91	0.23
Max	3587	1746	3.99	1.02
Min	985	510	0.98	0.25
	% Δ In Efficiency For Each Year =		-27.60%	
	% Variation in Efficiency Over The DCP =		308.77%	
Approximate person equivalents used at 148 hours/month:				
	Average =	7		
	Maximum =	12		
	Minimum =	3		

FDAC Selecting
Process Average
Oct 86 - Sep 88





HDB Cataloging
Process Average
Oct 86 - Sep 88
Increase in Efficiency
Decrease in Efficiency
Production Rate
2.50
2.00
1.50
1.00
0.50
0.00
O N D J F M A M J J A S O N D J F M A M J J A S
TR Cataloged/Labor-hour
Process Avg


HDS Transcribing
Process Average
Oct 86 - Sep 88
Production Rate
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Increase in Efficiency
Decrease in Efficiency
O N D J F M A M J J A S O N D J F M A M J J A S
TR Cataloged/Labor-hour
Process Avg

END
FILMED
5-89
DTIC